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(54) Electromagnetic machines

(57) An electromagnetic machine which may be, for example, a motor or a generator comprises a housing member (3,4) defining at least one tubular space (7) between inner and outer cylindrical surfaces. A plurality of electrically conductive rolling elements (1) are disposed in the space (7) and are supported by an equal plurality of rollers (2). Means for producing a constant or variable radially directed magnetic field across the space (7) is also provided.

Figure 7

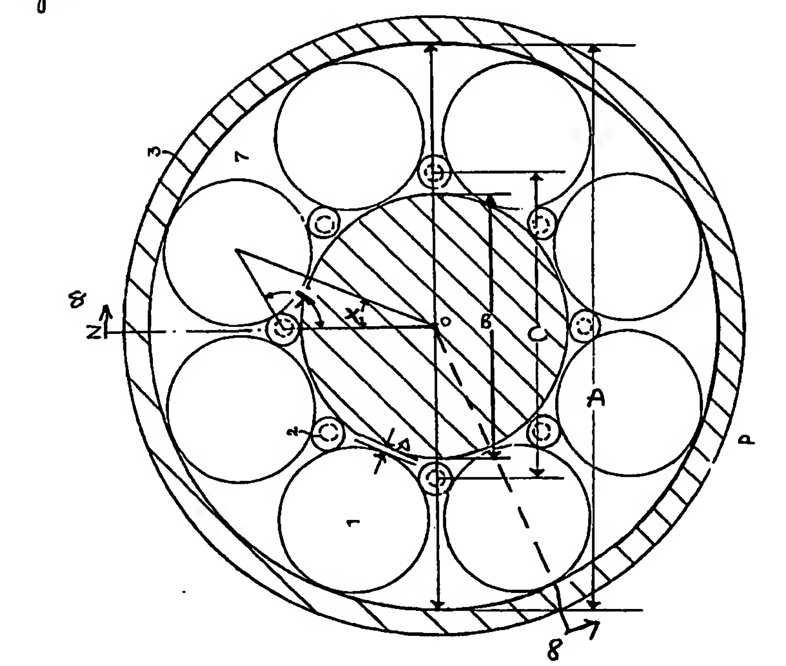

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Fig 1

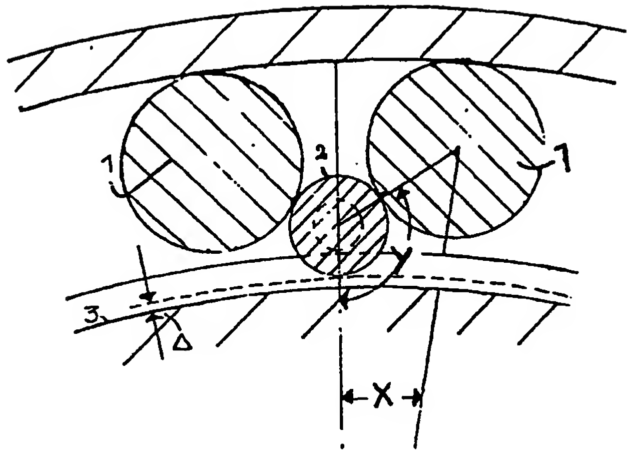


Fig 1A

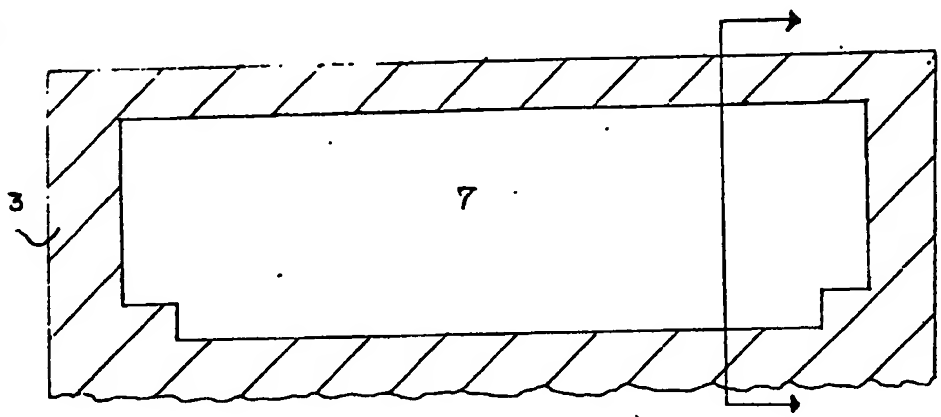


Figure 1B

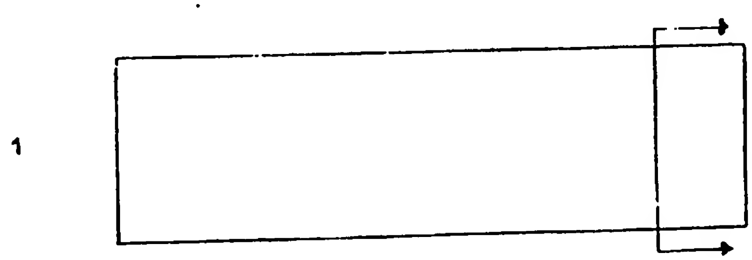


Figure 1C

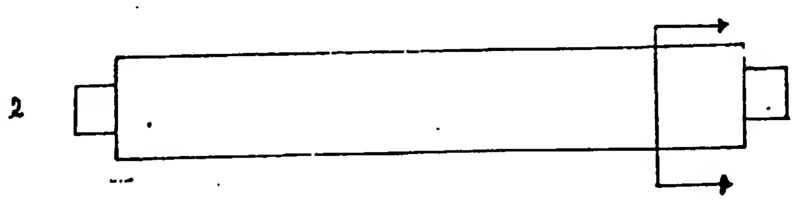


Figure 2.

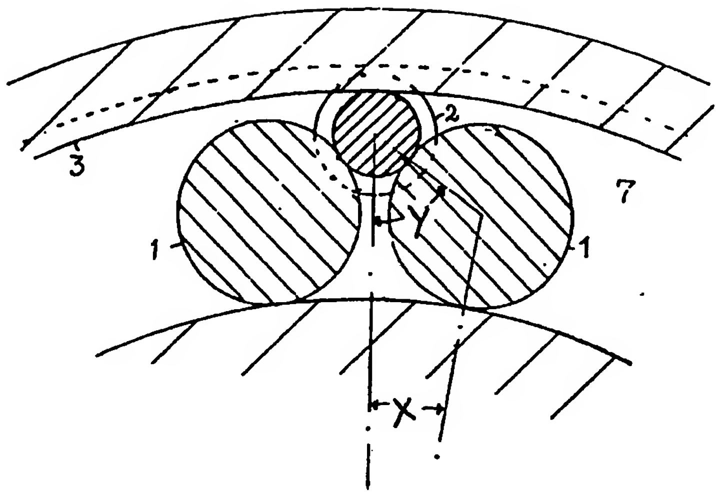


Figure 2A

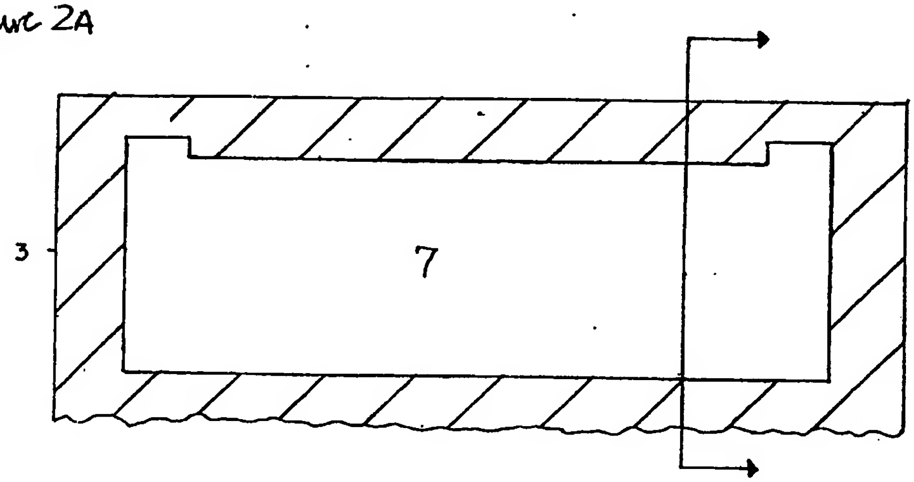


Figure 2B

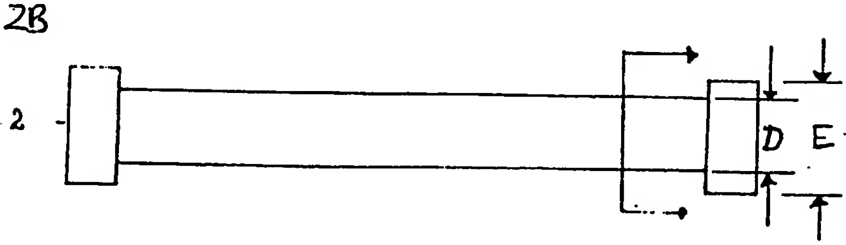


Figure 2C

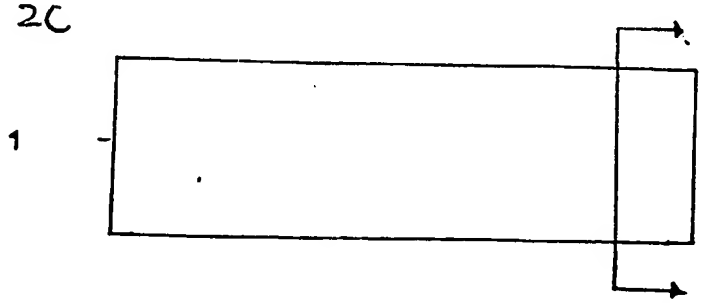


Figure 3

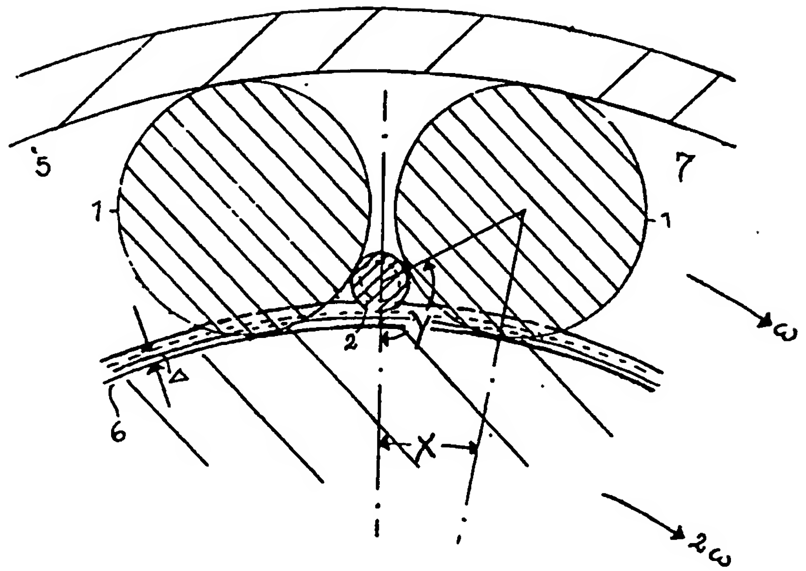


Figure 3A

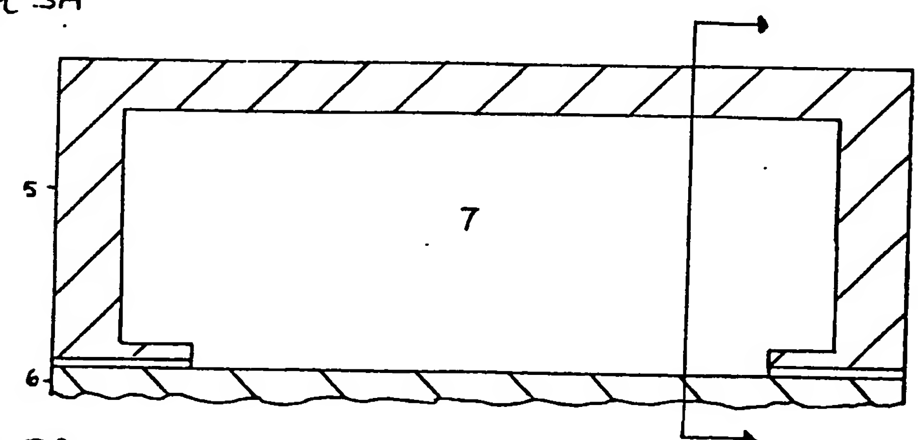


Figure 3B

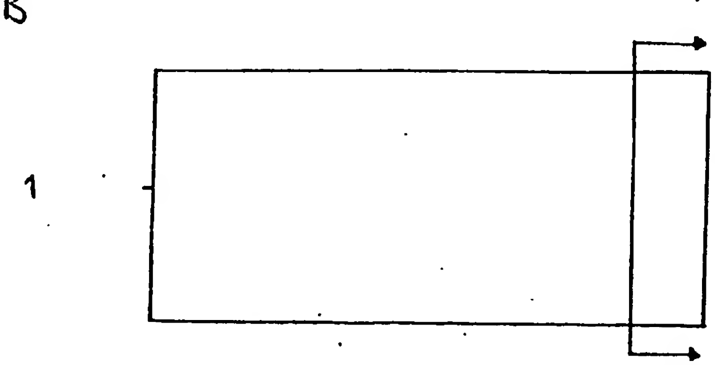


Figure 3C

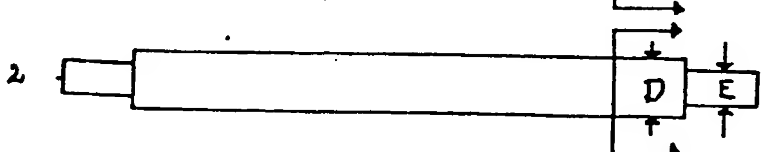


Figure 4

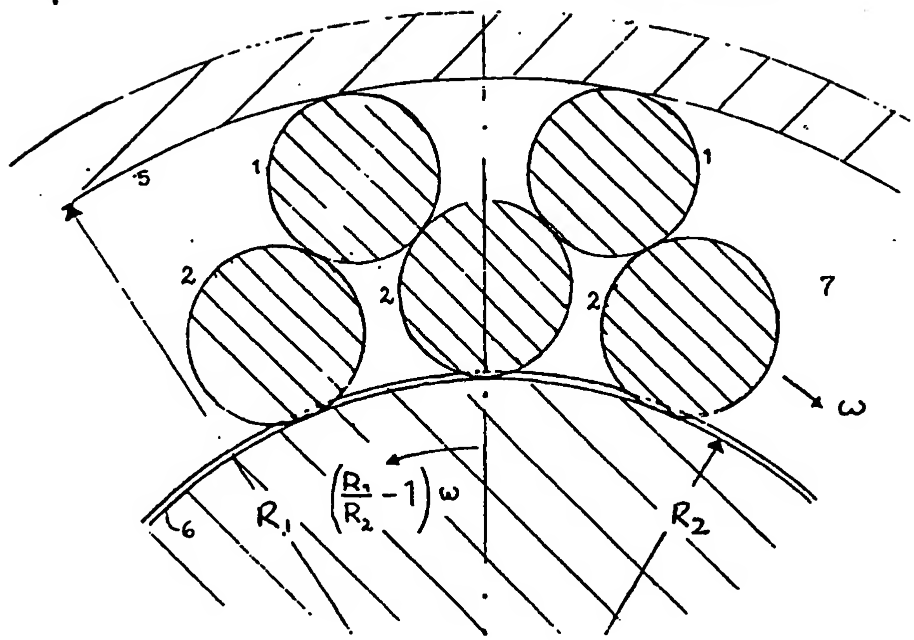
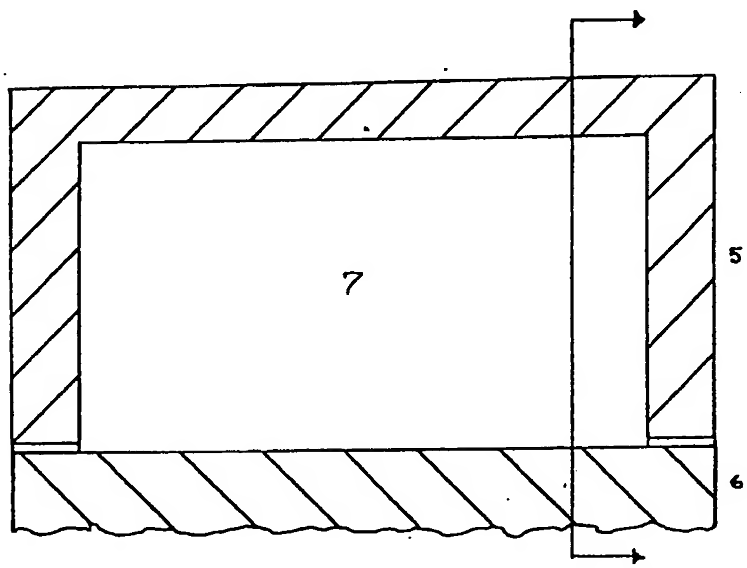


Figure 4A



gure 4B

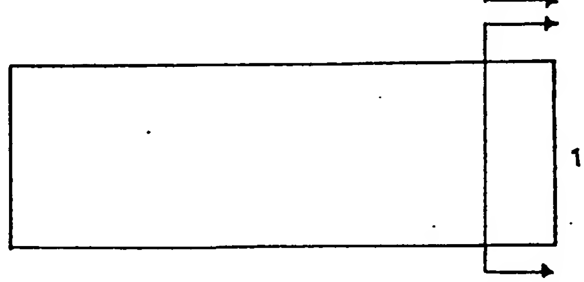


Figure 4C

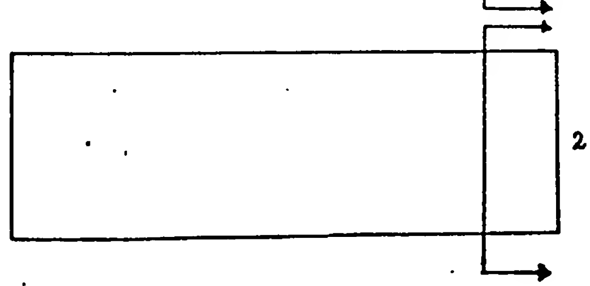


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Figure 5

Figure 7

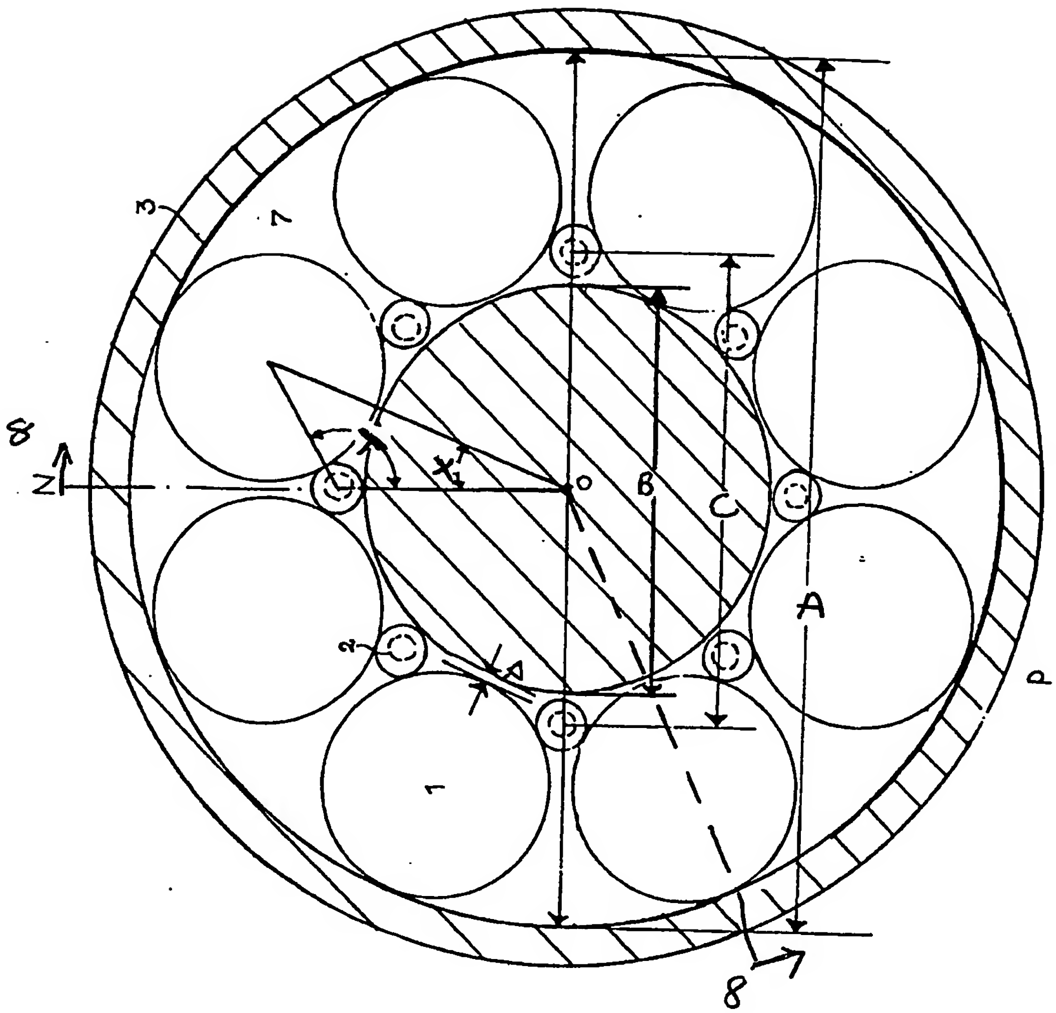


Figure 8

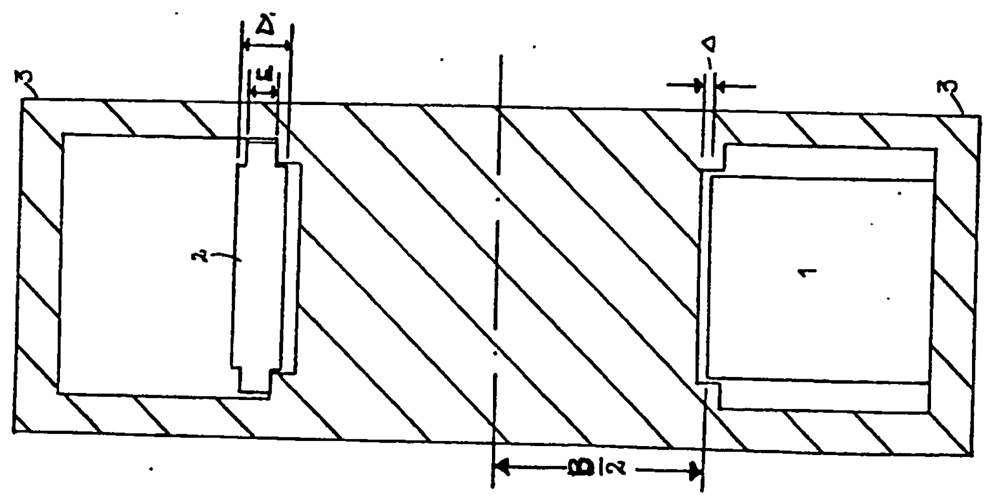


Figure 9

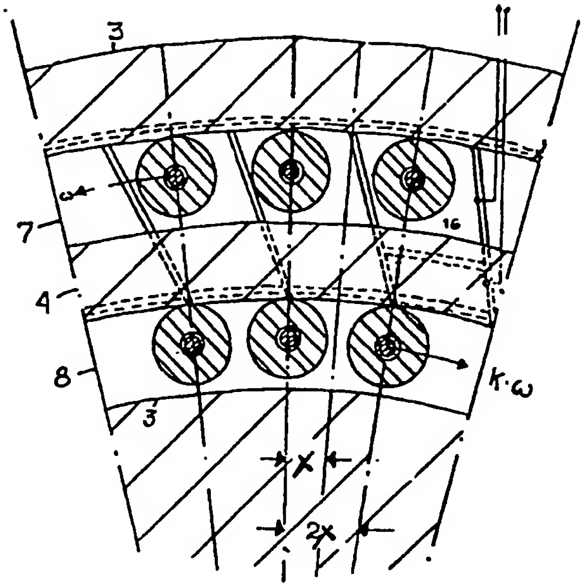


Figure 10

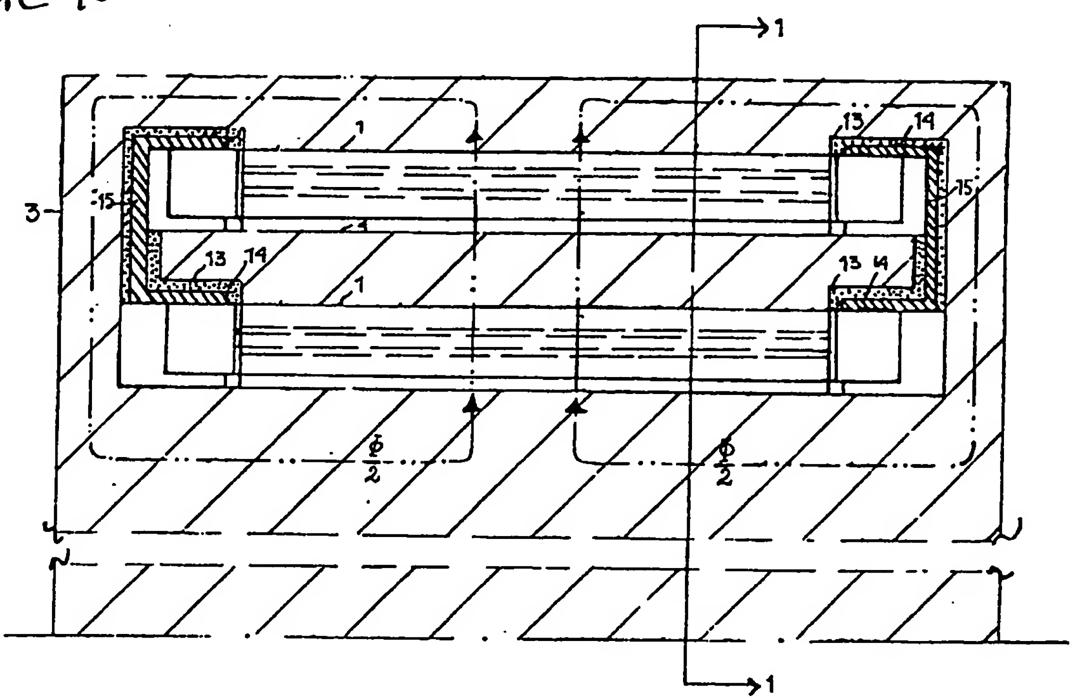


Figure 11

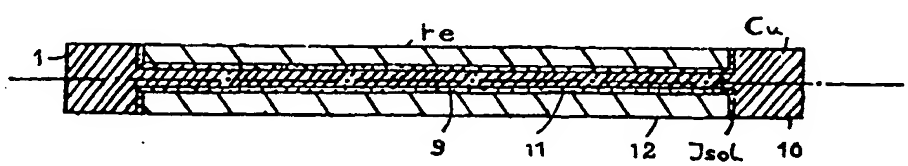


Figure 12

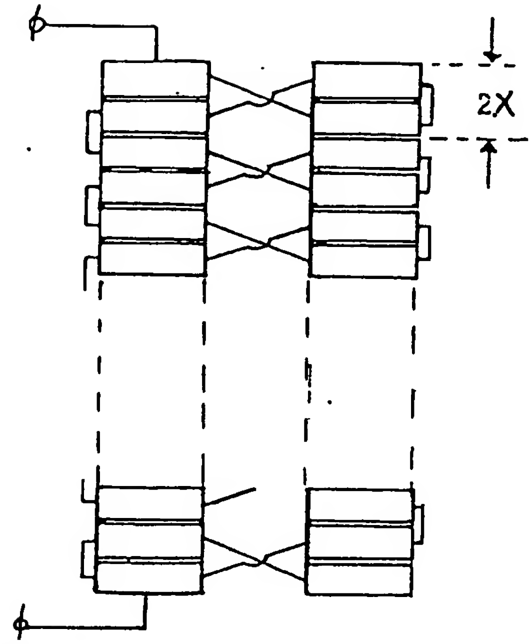


Figure 13

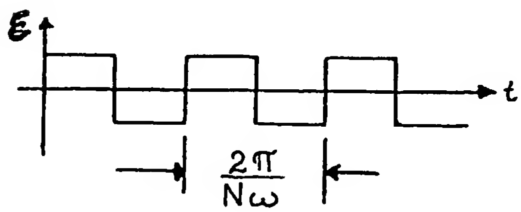
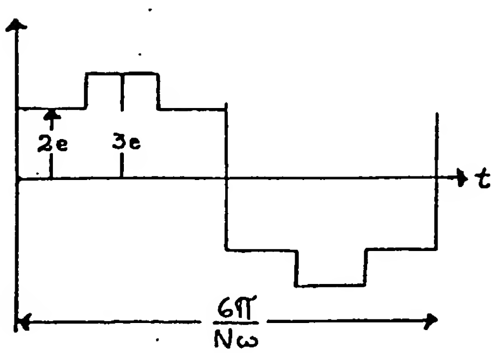


Figure 14



SPECIFICATION

Improvements in or relating to electromagnetic machines

The present invention relates to improvements in or relating to electromagnetic machines.

The machines of the present invention may utilise a physical construction as disclosed in United Kingdom Patent Application No. 41790/78 published as GB 2008204A relating to bearings the disclosure of which is incorporated herein by reference.

The present invention includes an electromagnetic machine comprising a tubular space defined between inner and outer races, means for producing a radially directed magnetic field in the space, and an equal plurality of alternately arranged rolling elements and rollers disposed for free movement within the space, at least the rolling elements being electrically conductive.

In order that the invention may be well understood several embodiments thereof will now be described, by way of example only, with reference to the accompanying drawings in which:

Figures 1 to *6* show partial transverse cross-sections through respective electromagnetic machines;

Figures 1A, 2A, 3A and *4A* show respective longitudinal sections through housing members of the various relative machines;

Figures 1B, 2B, 3B and *4B* show respective longitudinal sections of rolling elements used in the various relative machines;

Figures 1C, 2C, 3C and *4C* show respective longitudinal sections of rollers used in the various relative machines;

Figure 7 shows a transverse cross-section through another electromagnetic machine;

Figure 8 shows a section on the line 8-8 of Figure 7;

Figure 9 is a partial transverse cross section of yet another type of electromagnetic machine having two coaxial tubular spaces with rollers omitted for clarity;

Figure 10 is a partial longitudinal cross-section through the machine of Figure 9;

Figure 11 is a section through a conducting rolling element of the machine of Figures 9 and 10;

Figure 12 shows a method of connecting the conducting rolling elements of the machine of Figures 9 to 11; and

Figures 13 and *14* show different waveforms which may be produced from the electromagnetic machines described when used as generators with the conducting rolling elements suitably interconneced.

The actual invention shows new constructi ns f electrical motors, accumulators etc., achieved by arrangement in groups of usually serial-connected electrical conductors, which r lling fr ely r tate in a radial magnetical flux. Fr m the invention it is clear that electrical currents and voltages can b transformed and that electrical power/en rgy can be transferred to r tating mechanical power/energy as well as transf rmed in the opposite direction. The invention also includes quite new types f mechanically activ energy-units.

The in kn wn lectrical apparatuses used induction-effect $E_i = d\phi/dt$ and the force-combine $F = I \cdot B \cdot L$ is normally not directly coupled to rotational energies of the form $I \cdot \omega^2/2$. For transforming voltages and currents without the mechanical way via rotating converters only alternating fields have been used for the $d\phi/dt$-effect. Further it is valid for rotating electrical apparatuses that the active electrical conductors are rigid connected with rotating masses. The needed magnetic flux passes an apparatus section, space- or unit-fixed.

One of the main principles in the actual invention is based upon, that only the current-carrying conductors circulary rotate in a radially directed magnetic flux and and that the magnetic-field producing unit as normally has not to be fixed in space.

A first main principle points out methods to carry out this rotation of the current conductors within the magnetic unit with a sliding- and frictionfree- rolling off of the conductors between the surrounding cylindrical surfaces, also compare the U.K. patent application No 41790/78 regarding roll-bearings. An even number (2·N) specific formed rolls respectively supporting rolls and to them an adapted cylindrical cavity, 7, in Figures 1-11, is on that point a condition.

The invention indicates two main groups of this mechanical functioning of the rolls. In the first case the rolls, 1, in Figure 1,2,9,10,11 at continuous and constant rotational velocity, are completley free from tangential influence from or on the surrounding system, 3, in Figures 1, 2, 5 and 6, and the parts, 3 and 4 in Figure 9, 10, 11, of the system. In the second case the rolls cooperate mechanically by friction contact with the surrounding system as shown in Figures 3 and 4. This surrounding system is then formed by two mutually free rotating and concentric system-halves, 5 and 6 in Figure 3 and 4.

With reference to Figure 1, 2, 3, 5 and 6 respectively and patent claims 2, 4 and 5 it is clear how every second supporting roll, 2, and its centre of axis with Y<90 degrees, see Figure 2, radially is placed outside or with Y>90 degrees, see Figure 1, 3, 5 and 6, is placed inside the plane through the centers of the axis of the nearby rolls. An univocal ratio of radius of the supporting rolls for slidingfree rolling and rotation is achieved from formulae in the aforementioned UK Patent Application No 41790/78. The measures and angles given in the Figures and the formulae define the actual ratio of the radius. There is also a possibility with completely cylindrical supporting rollers or rolls, 2, to give the rolling elements or main rolls, 1, an univocal ratio of radius. For such variants somewhat changed but not nearer specified formulae are valid. The same is also p ssible for a combination f different ratio of radius for b th r lls and supp rting rolls. The even number f all rolls, the absolut values of th radius f rolls and cavity as w ll as th axial dimensions are optional free within wide limits. An upper r spectively l wer limit, Δ, in Figures is given from pat nt claim 5 for one f th radius of the cavity.

In Figures 9 to 11 one ex cution with double, concentric caviti s mainly adapted for accumulating

energy has been sh wn, ther simplified and drawn with only one half of all rolls, 1, in the cavity and then for the case Y>90 degrees. Other executions with a number of concentric systems of rolls makes a good exploitation of the volume and by that way a high energy-density. How the fluxes in the different cavities are produced and the possibilities to stear, distribute and vary these with known methods has been passed over, because the main principles of the invention are not affected of that.

Lowest in Figure 11 is shown one of many executions of the rolls, 1, with electrically conducting central- and end-parts, 9 and 10, with electrically conducting central- and the main part of the roll, 12, which suitably is made from a magnetically well conducting material. On both sides of the frame N number of collector sections are attached, 14, towards the frame and mutually isolated, 13, which form rolling-off surfaces as well as current connections for the roll-conductors. In the general execution with one cavity from Figures 1 to 6 from outside accessible and isolated connections to each collector section on both sides shall be arranged for serial and/or parallel connection of one or more groups of sections. In the model in Figure 9-11 for simple and internal serial connection of all roll-conductors the nearby segments, 14, for the two cavities have mutually been displaced by X degrees with intercoupling, 15, however, except one intercoupling, 16, which is used for outside current connectors. The X-angle is defined as $X = 360/2N$.

In Figure 9-11 and then when connected to an outer DC-voltage, current-limiting at upstarting with by example an inductance, the countermoving circular rotations of the two rollsections are commenced and reach these quickly the rotational velocities ω and $k\omega$ shown in the Figure with the relation $\varepsilon_i = \frac{1+k}{2} \cdot \omega \cdot N \cdot \phi$. The difference between the voltage from outside ε and the inner induced counter-emf ε_i is driving a current through the roll-conductors and the inner resistance R of the system. At rotational balance the idling current and its driving force and combined angular momentum will compensate actual friction-, hysteresis- and ohmic losses in the roll sections. If these losses are unequal for the two sections then $\omega \neq k\,\omega$, but an equality can be reached by an adapted flux density by shunting the field in one of the cavities, by a different current-distribution etc. The power consumption from the outer voltage source at a contineous rotation and at a low value of R will practically be independent of this resistance and proportional to the losses from friction and hysteresis. Because the friction losses especially at evacuated systems practically are non-existent and the other by an adapted ferromagnetic material in and an eddycurrent-limiting constructi n of the main part f the roll-conductors, the idling losses will be n glectable.

When the ut r voltage source is disconnected after a starting up f the system the inbuilt r tational energy will r main. The system will act as an electro-mechanical accumulat r. Th voltage adjustment when c nnecting an uter load is d n by regulating the fi ldstrength inv rse proportional to the speed f r volution. With ut an uter l ad th idling losses due to hysteresis can be reduced to zero by a total demagnetizing, $\phi = 0$. This gives an opportunity to a longduring energy conservation, only limited by the losses of the hysteresis type of mechanical deformations due to centrifugal forces respectively to losses from micro-sliding.

For a maximal conservation of energy the rolls of the system shall space-rotate with a maximal allowed surface speed of v m/s with an accepted security margin to the explosion limit of v_{max}. This means, because the surface speeds will be proportional to the outer radius of the actual cavities, that the rotation speeds of the sections shall be adjusted inverse proportional to these radius with by example adjusted flux densities.

In the general case with equal directed circular rotations the rollstored rotational energy also can be transformed to rotational energy of the system surrounding the cavity or cavities if this system is fixed to a shaft with bearings, i.e. if it is given a motor performance. The transformation is done by shortcircuiting of the connections to the collectors respectively by adjustment of the magnetic flux. Without an outer mechanical load on the shaft of the system such an energy transfer and a total rotation of the system will be achieved optionally quick so that the relative rotation between system and rolls, the internally induced emf and then also the current through the roll-conductors ceases. However, if the shaft simultaneously is loaded with an outer torque, i.e. that the arrangement is functioning as a driving motor, finally the situation is reached, when all internal and relative rotational energy is transferred to the outer load and the driving force disappears.

Continuous and constant motor action is achieved from above described effects with a time controlled and alternating switching between energy conservation and energy delivering. The inertia of the load will then equalize the pulsations. During the period of energy storing the reaction of the system shall not react on the load but shall be transferred and coupled to the frame, which by example means an addition of a counterrotating free-coupling to the load.

The alternative is a simultaneous intake and outtake of energy. A suitable choosen part of the roll-system, and most simple then at systems with one cavity, will then function as shortcircuited with an electromagnetical locking effect between the outer energy consumption and the internal energy of the roll-system. Other parts of the roll-system are given rotational energy from electrical energy via to these parts belonging, open collector contacts, which then are connected to an outer voltage source. The alternating switching of turning forces to rotor respectively frame can be arranged with tw alternatively functioning flux systems, f rmed in rotor respectively fram . The systems f rolls and fluxes shall then b giv n simultane us activities.

The task to transfer electrical en rgy to other forms of l ctrical energy, i.e. voltage- and current transf rmation, is solved by using th step-transf rmer-like contacts from the collect rs of the serial conn cted roll-conduct rs. Alternatively fr m

each other electrically separated part-groups of the total number f active r lls are used. This gives current-ratios following the known transformer expression $I_1 N_1 = I_2 N_2$ = etc. and voltage-ratios from $V_1/N_1 = V_2/N_2$ = etc.

The inverted motor performance, i.e. generating electrical energy from mechanical with its symmetrical characteristics have not to be described. In the same way as has been explained in the above motor section current is forced back to the voltage source $E(I{\cdot}R_y)$ when the outer connected momentum forces the rotational direction to change sign and $E_I = I(R + R_y)$ or $E_I = IR + E$.

For adaption of ordinary AC-lines to the above described electromagnetical systems and then in the first case for motors, converters and accumulators it is necessary that the magnetic field shall vary synchronously with the outer voltage source, suitably then with parallel feed fieldwindings. For AC-generators as for converters from DC to AC Figure 12 is referred to where midparted and crossconnected collector segments will deliver square-formed AC when magnet-flux is constant. The amplitude of this flux determines the rotation frequency from $\omega = 2\pi{\cdot}E/N{\cdot}\phi$ and from that the pulse-frequency $f = E/\phi$. If a more sine-formed outgoing voltage asked for, every collector segment can be divided into an even number of partsegments, by example 6, with a curve form given in Figure 14, alternatively filtrated with known methods or generated by a controlled and sine-formed magnetic field-flux etc.

As a mechanical alternative to the above described forms in Figures 1,2,5,6,9,10 and 11 with a the cavity/cavities surrounding homogenus system it is shown in Figure 3 a parted system for Y>90 degrees comparable to an ordinary motor/generator with one stator and one rotor unit. The roll-conductors and then each half the number of these, N, have direct contact with the outer respectively the inner radius of the cavity. Electrical energy is transferred to rotational energy via tangential forces. This is also true for the form with Y<90 degrees which can be compared with Figure 2, where, however, the rolls shall have contact with the surrounding cylindrical surfaces. The rotor-rotation here will be equal to the double rotation of the roll-conductors in the same manner as in an usual rollbearing. The reluctance in the cavity is here decreased because there is only two bypassing-areas for the part-flux through one roll-conductor but is increased totally at the same time by the free-running distance, Δ, between the outer and inner parts of the system. In another alternative form with cog- or splines-formed roll-conductors the supporting rollers can disappear because the angle-division between individual rolls can be maintain d by adapt d gearpitch n the rolls and the cylindersurfaces.

Still an ther alternative with a stator-rotor construct n is given in Figure 4 with th possibility to use conf rm and eventually qually big outer and inner r ll-conductors with ut specific ratio f radius. Th r tati n f the rolls and the rot r will be count rdirected with a forceful downgearing and thus suitable for motor/g nerators with l w speed.

Beyond th above described applicati ns which look like known electromagnetical systems the field will open, especially for forms with a homogeneous and closed outer magnet-system, for a number of unique applications. As some examples following may be mentioned:

1. energystoring, starting, rolling, braking with energystoring and backing weels, externally controlled,
2. torque-activators on shafts, levers and similar, without outer mechanical contact,
3. gyrofree energystoring by adapted inertia of the counterrotating components,
4. energystoring buffert systems in power-lines,
5. pulsgenerators,
6. mechanically elastic equalizers at mechanical transmissions,
7. frequency converters etc.

CLAIMS

1. An electromagentic machine comprising a tubular space defined between inner and outer races, means for producing a radially directed magnetic field in the space, and an equal plurality of alternately arranged rolling elements and rollers disposed for free movement within the space, at least the rolling elements being electrically conductive.

2. An apparatus comprising a rotating electromagnetic system nearest replacing electrical motors, generators, converters and energyaccumulators mainly with radially directed magnetic field, defined by that across the magnetic field freely movable conductors (1 and 2) rotate in circular traces (7) and that from an even number of rolling conductors each other conductor is rolling off an outward limited and inward turned cylindrical surface or surfaces and the outer rolling off an inward limited and outward turned cylindrical surface or surfaces and that nearby conductors roll against each other.

3. An apparatus according to Claim 2, defined by that the unit (3) surrounding the cylindrical hollow, limited by the two against each other turned surfaces, is homogeneous and mainly made from magnetic material with devices for constant or variabel magnetic fluxgeneration across the cylindersurfaces.

4. An apparatus according to Claims 2-3, defined by that the half number of or each half number of all roll-conductors are given two different rolling-off diameters (F and G) for rolling off partly against surrounding cylinder-surfaces partly mutually and that the diameterratio is so choosen that no or eligible big sliding occurs.

5. An apparatus according to Claim 2-4, defined by that one of the cylindersurfaces surrounding th cylindrical hollow, of which one part of that surface is in contact with th se r ll-conductors given tw diameters and then ne of those diameters (F), the other part is given such a diam ter that it will not touch but is nearby that part f the r ll-conductor which has been given the ther diameter.

6. An apparatus according t Claim 2,4, and 5, defined by that the against each other turned cylindersurfaces are f rmed by an outer (5) and an

inner unit (6) which mutually can rotat .

7. An apparatus according Claim 2, 4, 5, and 6, defined by that half f the ev n number of roll-conductors mutually are rolling off the in Claim 5 specified and mutually free rotating units (5 and 6), and that the other half number of the roll-conductors are rolling off someone of the surrounding cylinder-surfaces and nearby roll-conductors.

8. An apparatus according to Claim 2,4,5,6, and 7, defined by that each half of the even number of roll-conductors each of them are rolling off the nearby and in Claim 5 specified and mutually free rotating units (5 and 6).

9. An apparatus according to Claim 2-5, defined by that coaxially a number of several cylindrical hollows (7, 8 e.t.c.) are filled with mutually with- or counter-rotating rollsystems.

10. An apparatus according to Claims 2-9, defined by that the roll-conductors or sections of them mutually and also against surrounding cylinder surfaces are electrically isolated (11) and with electrical contact (10) are rolling off endplaced and in the other system fixed current collectors (14).

11. An apparatus according to Claim 2-10, defined by that the current carrying roll-conductors or sections of them (12) are made from material with high magnetic conductivity.

12. An apparatus according to Claims 2-11, defined by that to diminish the friction-losses the circular hollow/hollows completely or partly are evacuated.

13. An apparatus according to Claims 2-5, defined by that to get lowest possible gyroeffects in the total system the weight of the rolls and their inertia with reference to their absolute directions of rotation are so formed that their contribution to the total sum of inertia completely or partly is cancelled.

14. Any of the electromagnetic machines substantially as herein described with reference to the accompanying drawings.

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